Stress and selective attention: The interplay of mood, cortisol levels, and emotional information processing

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Abstract
The effects of a stressful challenge on the processing of emotional words were examined in college students. Stress induction was achieved using a competitive computer task, where the individual either repeatedly lost or won against a confederate. Mood, attention, and cortisol were recorded during the study. There were four findings: (1) Participants in the negative stressor condition were faster to shift attention away from negative words than positive or neutral words; (2) attentional shifts away from negative words were associated with stress-induced mood lowering; (3) participants in the negative stress condition with elevated scores on the Beck Depression Inventory were slow to disengage attention from all stimuli; and (4) elevated depression scores were associated with lower cortisol change from baseline during the experimental phase, and with higher cortisol levels during the recovery phase. These findings point to information-processing strategies as a means to regulate emotion, and to atypical features of cognitive and adrenocortical function that may serve as putative risk markers of depression.

Descriptors: Stress response, Selective attention, Emotional stimuli, Cortisol, Emotion regulation

There is considerable evidence linking stress with physical illness and psychopathology (Kaufman, Plotsky, Nemeroff, & Charney, 2000; Post, Leverich, Xing, & Weiss, 2001). Studies have also documented differences in stress-related response patterns between normally functioning adults, those who commit major criminal offences (Virkkunen, 1985; Woodman, Hinton, & O’Neill, 1978), and those clinically depressed or anxious (Holsboer, 1995; Kagan, Reznick, & Snidman, 1988; Mogg & Bradley, 1998). Work of this kind has stimulated interest in the processes and mechanisms implicated in stress-related behavior. The present study intended to examine the unfolding of events following a stressful challenge, from emotional state and adrenocortical activity, to ensuing processing of emotional information.

Motivational Influences on Attention
Shifting attention in space may be an important factor in determining how the organism will perceive and interpret environmental information, and thus it may represent an early influence on goal-directed behavior. Derryberry and colleagues (for review, see Derryberry & Tucker, 1994; Reed & Derryberry, 1995) have shown that both experimental manipulations of motivational state and individual differences on trait dimensions of neuroticism and extraversion can influence attention and information processing. Normal volunteers, after fasting for 16 to 22 hr, were more likely to allocate attention to food-related words than neutral words on a dot probe attention task (Mogg, Bradley, Hyare, & Lee, 1998). This effect was not observed in nonfasting participants, suggesting that changes in attention took place following the induction of a hunger state. Finally, a large body of clinical literature indicates that selective attention to threatening information supports and sustains maladaptive patterns of information processing characteristic of anxious and depressive states (McNally, 1998; Mogg & Bradley, 1998). These studies suggest that selective attention is sensitive to affective-motivational states. From this perspective, it is plausible that biases in attention may occur in response to stress.

Although certain studies have found that laboratory stressors and mood induction procedures facilitate the processing of threatening information (Bradley, Mogg, & Lee, 1997; Chen, Lewin, & Craske, 1996; Gilboa & Gotlib, 1997; Mogg, Mathews, Bird, & Macgregor-Morris, 1990), others have failed to replicate these findings (Mathews & Sebastien, 1993; McNally, Riemann, Louro, Lukach, & Kim, 1992; Mogg, Kentish, & Bradley, 1993). Inconsistent findings may be due, in part, to the wide variety of stressors used, including anxious mood induction, cognitive challenges, and physical exercise. These studies have also differed in the population examined (e.g., clinical vs. nonclinical) and in the types of negative stimuli used. The stressors and stimuli selected in these studies were not always relevant to the affective state of the individual, and thus they may not have been sufficiently salient to
influence attention. Alternatively, attention may theoretically buffer, rather than exacerbate, the impact of stressful events. For example, the ability to use attentional processes for self-regulation represents an important predictor of later adaptive functioning in children (Derryberry & Rothbart, 1997). In sum, the tendency to orient and maintain attention to distressing information, as well as the ability to shift efficiently away from it, may represent important dimensions of coping, with implications for the development of stress-related forms of psychopathology.

**Stress, Adrenocortical Function, and Attention**

Few studies have examined the relationship between stress-induced hypothalamic-pituitary-adrenal (HPA) activation and mechanisms of selective attention. There is some evidence that the administration of exogenous corticosteroids and adrenocorticotropic-related neuropeptides (e.g., ACTH-4-10) impede selective attention (Kopell, Wittner, Lunde, Warrick, & Edwards, 1970; Wolkomitz, 1994), resulting in lower sensory acuity (Fehm-Wolfsdorf et al., 1993; Fehm-Wolfsdorf, Scheible, Zenz, Born, & Fehm, 1989) and a decreased ability to filter out extraneous or nonrelevant information (Mölle, Albrecht, Marshall, Fehm, & Born, 1997). Recently, stress-induced cortisol levels were associated with decreased inhibition of nonrelevant information on a negative priming task, a standard measure of inhibitory attentional processes (Skosnik, Chatterton, Swisher, & Park, 2000). Thus, moderate elevations of cortisol may alter information processing by impeding focused modes of attention, a finding that is consistent with some arousal and motivational theories of attention (Easterbrook, 1959; Tucker & Williamson, 1984). However, a number of studies have not found a relationship between attention and cortisol (Newcomer, Craft, Hershey, Askins, & Bardgett, 1994; Schmidt, Fox, Goldberg, Smith, & Schulkin, 1999; Wolkomitz et al., 1990). The use of different measures of attention, as well as the administration of different types and dosages of exogenous corticosteroid (Lupien & McEwen, 1997), may explain these discrepancies. Of importance in the present context is the dearth of studies on the relationship between HPA activation and attention to emotional stimuli. Two recent studies (Epel, McEwen, & Lupien, 2000; van Honk et al., 2000) have reported that stress-induced cortisol reactivity was positively associated with selective attention to emotional stimuli. Because appraisal and perceived coping ability are important determinants of the adrenocortical response to stress (Breier, 1989; Schwartzman & Austin, 1998; van Eck & Nicolson, 1994), cognitive processes such as selective attention to emotional stimuli may be paramount in modulating the HPA response to threat or challenge.

**Goals of the Present Study**

We examined the premise that aversive stress facilitates the processing of negatively valenced verbal information, and further, that attention to negative stimuli is associated with higher cortisol levels. Healthy university students competed against a confederate on a computer task for monetary reward. They either won (positive stress) or lost (negative stress) repeatedly, or performed the task with no competition and reward (neutral condition). Repetitive loss, or the negative stress condition, was meant to create a negative motivational-emotional state, where participants experience failure, irrespective of effort, within a social context. This manipulation was meant to incorporate several features believed to be important in eliciting the experience of subjective stress and concomitant activation of the HPA axis, such as the use of an aversive contingency (Lovallo, Pincomb, Brackett, & Wilson, 1990), an inability to control the outcome (Breier et al., 1987), social evaluation (Kirschbaum, Pirke, & Hellhammer, 1993), and subjective distress (Henry, 1992). Repetitive winning, or the positive stress condition, was meant to elicit the same amount of effort as the negative stress condition, but with a sense of control and with positive affect. Following the stressful challenge, participants performed a selective attention and recognition memory task. Throughout the experiment, salivary cortisol and mood state were measured. Selective attention was assessed using a modified spatial cueing task (Posner, 1978; Stormark, Nordby, & Hugdahl, 1995), designed to measure the efficiency in which covert attention is shifted towards (engagement) and away (disengagement) from emotional or neutral stimuli. It differs from previous measures of attention, which have typically assessed only attentional engagement or allocation. In addition, words used in this task were chosen to match the success–failure dimension of the stressor.

Five hypotheses were tested. First, it was predicted that the negative stressor would elicit greater negative mood change and higher cortisol levels than the positive stressor or neutral conditions. Second, previous research on clinical populations with anxiety and depression (Mogg & Bradley, 1998), as well as studies using experimental manipulations of mood or motivation in normal samples (Bradley et al., 1997; Mogg et al., 1998), suggest that affective-motivational states influence attention by facilitating the processing of mood-congruent information. Therefore, it was hypothesized that under conditions of repetitive loss, participants would selectively attend to negative stimuli, primarily through delays in shifting attention away from negative stimuli. Third, it was predicted that participants with self-reported depressive and/or anxious symptoms, as indexed by elevated scores on the Beck Depression Inventory and/or State-Trait Anxiety Inventory, would exhibit increased selective attention to emotional information and a higher cortisol response to stress than participants with low scores on these rating scales. This hypothesis was based on the fact that abnormalities in information processing and HPA function are well documented in depressed and anxious populations (Holsboer, 1995; Mogg & Bradley, 1998). Fourth, it was predicted that participants with elevated cortisol levels would selectively attend to negative stimuli, as suggested by two recent studies (Epel et al., 2000; van Honk et al., 2000). Finally, the proposition that attention can mediate the impact of stress on the individual was tested. It was hypothesized that selective attention to negative stimuli would be associated with poor cortisol recovery following stress, as indexed by higher cortisol levels during the recovery phase of the experiment.

**Method**

**Participants**

Student participants, 18–36 years of age, were recruited for a study on cognitive ability during competition through college newspaper advertisements and visits to classrooms. All participants were right-handed, had normal or corrected-to-normal vision, and were English-speaking or demonstrated an adequate understanding of English on a fluency test. The criteria for exclusion of subject candidates were: (1) pregnancy/lactation; (2) regular usage of prescriptive medication, except that for birth control (women who were in the midst of changing birth control procedures were excluded); (3) color blindness; (4) current psychiatric disorder; and (5) any major medical condition. Of the 138 subjects meeting inclusion criteria, 3 participants were excluded from all analyses for failing to comply with the testing protocol. Thus, 135 participants (61 men; 74 women), with a mean age (± SD) of 23.8 ± 4.2,
were randomly assigned to the following groups: 47 (21 men; 26 women) participants in the negative stressor condition, 45 (20 men; 25 women) in the positive stressor condition, and 43 (20 men; 23 women) in the neutral condition.

**Measures**

All participants were assessed with tests for color blindness (Ishihara, 1964) and English reading comprehension (Aitken, 1977), and a brief semistructured psychiatric interview based on the Structured Clinical Interview for DSM-IV (First, Spitzer, Gibbon, & Williams, 1997). The latter assessment included questions pertaining to substance use, depression, anxiety, psychotic symptoms, mental health treatment, and major medical conditions.

Emotional response during the course of the study was measured using the bipolar form of the Profile of Mood States (McNair, Lorr, & Droppleman, 1988). This test consists of subjective ratings of 72 adjectives describing six mood states: agreeable–hostile, composed–anxious, elated–depressed, confident–unsure, energetic–tired, and clearheaded–confused. It is sensitive to mild changes in mood state in nonclinical populations (Ellenbogen, Young, Dean, Palmour, & Benkelfat, 1996). Other questionnaires administered included the Beck Depression Inventory (Beck, Ward, Mendelson, Mc, & Erbaugh, 1961) and the Spielberger Trait-State Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983).

**Modified Spatial Cueing Task**

In this task, participants fixated on a centrally placed black “+” sign on a white background, which was flanked on both sides by a rectangle. The goal of the task was to respond with a single key press as fast as possible when the target (an asterisk) appeared in either of the rectangles. Preceding all target presentations, a pre-target cue appeared in one of the rectangles. The cue, which was either a positive, negative, or neutral word, was indicative of the most likely location of the target on each trial. Participants were informed of this information, but were not instructed to read or pay attention to the meaning of the pretarget word cues. There were 576 trials in total, divided into 12 blocks (4 blocks for each word category, in random order) of 48 trials. Trials were either validly or invalidly cued. On valid or engagement trials (384), the target appeared in the same hemifield of the cue. On invalid or disengagement trials (96), the target appeared in the hemifield opposite of the location where the cue appeared. The stimulus onset asynchrony (the interval between the onset of the cue and onset of the target) for valid and invalid trials was 360 ms, and the interval between trials (from the offset of the target to next cue onset) was either 1.85 or 1.35 s. Targets were presented for 500 ms, and cues for 290 ms. An additional 96 trials (72 valid and 24 invalid) served as “catch” trials; the target appeared 790 ms after the cue appeared. Catch trials were meant to prevent participants from developing an automatic response set due to the fixed cue–target interval in this experiment, and were not included in the statistical analyses.

Participants performed the task in a chin rest 57 cm away from the monitor. The rectangle boxes had a visual angle of 2.2° (1.7 cm) in height and 2.6° (2.2 cm) in width. The center of each rectangle was 1.9° of visual angle from the fixation point. In pilot participants, words presented at this visual angle could be read while maintaining fixation on the centrally placed + sign (fixation point). Within each block, all pretarget cues were from the same word category, and stimulus presentation was equally distributed between the right and left visual hemifields. Validly and invalidly cued targets (including catch trials) represent 79% and 21% of all trials, respectively, a ratio shown to be effective in cueing attention (Posner, 1978). The dependent measures on this task were reaction time to respond to validly cued and invalidly cued targets for negative, positive, and neutral words in milliseconds.

Words used in the modified spatial cueing task were 16 negatively valenced words denoting failure and loss (i.e., loser, inferior), 16 positively valenced words denoting success and reward (i.e., winner, victory), and 16 neutral words denoting furniture or time (i.e., table, duration). The affective content of words used in the study were validated by ratings from an independent pilot sample of 40 students (20 men and 20 women). All words were between 4 and 8 letters long, and ranged from 0.58° × 1.45° (0.3 × 1.1 cm) to 0.58° × 2.57° (0.3 × 2.0 cm) of visual angle. Negative, positive, and neutral words were matched for word length and frequency usage (Carroll, Davies, & Richman, 1971). The words used in this study are listed in Appendix 1. The spatial cueing paradigm was run on a Power Macintosh 4400/200 with a 15-inch Apple Multiple Scan color monitor. The task was presented using the PIXX (version 1.49) software developed by the Visual Perception Lab of Concordia University (Montréal, Canada).

**Word Recognition Test**

Participants were asked to indicate which words out of a list of 120 had served as pretarget cues on the previous attention task. All neutral, positive, and negative pretarget cues were included in the test, along with another 60 distractor words (20 from each word category). The dependent variable was the mean number of correctly identified target words.

**Cortisol Sampling**

The salivary cortisol sampling procedure was an adaptation of that used by Stahl & Dorner (1982). Participants were asked to hold a strip of filter paper (Whatman qualitative 1, Whatman International Ltd., Maidstone, UK), 65 mm × 25 mm, under their tongue until it was saturated with saliva. Saliva samples were then air dried, and frozen at −20 °C until they were assayed for cortisol. Cortisol levels were determined via specific radioimmunoassay using a commercial kit (DSL-2000; Sanofi Diagnostics, Montréal, Canada), with previous ethanol extraction. All assays were performed at the Douglas Hospital Research Laboratories (Montréal, Canada). Intra-assay and interassay variability (4.6% and 13.9%, respectively) were within acceptable limits.

**Procedure**

Participants were screened by telephone regarding their medical and psychiatric history. They ate breakfast on the morning of the experiment, but refrained from eating for 1 hr prior to arrival at the laboratory. Participants commenced the experiment between 11:45 a.m. and 12:15 p.m. with the screening procedures. The study began with a baseline relaxation period of 30 min. In a dimly lit room with relaxing music, participants were instructed to rest in a comfortable chair and were allowed to read magazines. Participants were then randomly assigned to one of three stressor conditions: a positive, negative, or a neutral control condition.

In the positive and negative stressor conditions, participants competed against a confederate, who was introduced as another participant taking part in the experiment. The participant and confederate were placed in adjacent rooms connected by a large window and an open door. Participants and the confederate performed a modified computerized version of the Stroop Colour-Word Interference Test (Blondin & Waked, 1991). Performance during 12 blocks or games was monitored for speed and accuracy.
and results of the participant’s performance were presented on the computer at the end of each block. Participants and confederates were instructed to respond as quickly and as accurately as possible, and were told that they would receive $1 for every game they won, but only if they won a minimum of four games. Unknown to the participant, wins and losses were under experimenter control, according to a preset schedule. Participants in the negative condition lost 9/12 games and did not earn any money. Meanwhile, they observed the confederate “win” $9. In the positive condition, participants won 10/12 games and were rewarded with $10. Feedback concerning wins and losses, as well as a monetary reward, was given by the experimenter at the end of each block, along with a standardized set of verbalizations for each condition. In the control condition, participants performed the Stroop task without a competitor, and received no monetary incentive or verbal feedback from the experimenter. Upon completion of the stressor task, participants immediately performed the spatial cueing paradigm in a different room, followed by the word recognition task. Following a 45-min rest period, all participants were debriefed. Participants completed the Beck Depression Inventory and the State-Trait Anxiety Inventory before leaving. Mood ratings were recorded prior to the relaxation phase and immediately following the stressor phase.

Salivary cortisol (16 samples) was measured at predetermined intervals, approximately 10–15 min apart, throughout the experiment. Indices of cortisol output, in micrograms per deciliter, were determined by the mean total production during four experimental phases: relaxation (Samples 4–6), stressor task (Samples 7–9), attention task (Samples 10–12) and recovery (Samples 13–15). The first three cortisol samples during the relaxation phase were excluded from analyses because they were subject to the novelty effect of coming to the laboratory for the first time. Sample 16 was also excluded because of abnormally high values, probably due to the anticipation of a meal at the end of the study. Change scores were computed by subtracting the low point achieved during the relaxation phase (Samples 1–6) from peak cortisol production during the stressor or attention phase (Samples 7–13) of the experiment. Indices of recovery were the lowest cortisol levels achieved during the recovery phase of the experiment (Samples 13–16). On average, the first sample was collected at 12:30 p.m. and the final one at 3:15 p.m. Participants were compensated $40 Canadian for time spent in the laboratory. All procedures were approved by the Concordia University Research Ethics Committee.

**Data Analysis**

Data were screened and adjusted for outliers and distributional anomalies that may have violated statistical assumptions. To correct for significant positive skewness, a square root transformation was performed on cortisol data and scores on the Beck Depression Inventory. An inverse transformation was performed on spatial cueing reaction time data to correct for significant positive skewness. Statistical analyses were performed on transformed data, but figures and tables will present original data for interpretation purposes. For the spatial cueing task, all reaction times less than 150 ms and more than 850 ms were excluded from the analysis. Mood ratings on the Profile of Mood States (POMS) were analyzed as change scores (poststress minus baseline). Ratings from the six POMS scales were assessed using a MANOVA, with stressor condition (negative, positive, neutral condition) as an independent variable. Wilks’ lambda was used to assess multivariate significance; univariate results were only examined if multivariate significance was achieved. The influence of the experimental conditions on attention was analyzed by three-way mixed design ANOVAs (Stressor Condition × Word Valence × Hemifield) for valid and invalid trials. Stressor condition was the between-subjects variable, and stimulus valence (negative, positive and neutral words) and hemifield (left and right) were within-subject variables. Planned comparisons were used to compare negative words with positive and neutral words within each of the stressor conditions. To control the overall a level when conducting multiple planned comparisons, alpha levels were determined by Bonferroni correction. When three or six tests were conducted, we adopted alpha levels of 0.02 (0.05/3) and 0.01 (0.05/6), respectively, to maintain a familywise error term of approximately 0.05. Cortisol was analyzed using a Stressor Condition × Experimental Phase (relaxation, stressor, cognitive tasks, and recovery) mixed-design ANOVA. Hierarchical multiple regression analyses were used to examine the association between baseline state variables (Beck Depression Inventory and State-Trait Anxiety Inventory), mood change, attention, and cortisol.

The homogeneity of covariance assumption for all MANOVAs was assessed using Box’s M test. All within-subject effects were Greenhouse–Geisser corrected for sphericity of repeated measures. The Greenhouse–Geisser epsilon ( contaminations that may have violated statistical assumptions. To correct for significant positive skewness, a square root transformation was performed on cortisol data and scores on the Beck Depression Inventory. An inverse transformation was performed on spatial cueing reaction time data to correct for significant positive skewness. Statistical analyses were performed on transformed data, but figures and tables will present original data for interpretation purposes. For the spatial cueing task, all reaction times less than 150 ms and more than 850 ms were excluded from the analysis. Mood ratings on the Profile of Mood States (POMS) were analyzed as change scores (poststress minus baseline). Ratings from the six POMS scales were assessed using a MANOVA, with stressor condition (negative, positive, neutral condition) as an independent variable. Wilks’ lambda was used to assess multivariate significance; univariate results were only examined if multivariate significance was achieved. The influence of the experimental conditions on attention was analyzed by three-way mixed design ANOVAs (Stressor Condition × Word Valence × Hemifield) for valid and invalid trials. Stressor condition was the between-subjects variable, and stimulus valence (negative, positive and neutral words) and hemifield (left and right) were within-subject variables. Planned comparisons were used to compare negative words with positive and neutral words within each of the stressor conditions. To control the overall a level when conducting multiple planned comparisons, alpha levels were determined by Bonfroroni correction. When three or six tests were conducted, we adopted alpha levels of 0.02 (0.05/3) and 0.01 (0.05/6), respectively, to maintain a familywise error term of approximately 0.05. Cortisol was analyzed using a Stressor Condition × Experimental Phase (relaxation, stressor, cognitive tasks, and recovery) mixed-design ANOVA. Hierarchical multiple regression analyses were used to examine the association between baseline state variables (Beck Depression Inventory and State-Trait Anxiety Inventory), mood change, attention, and cortisol.

The homogeneity of covariance assumption for all MANOVAs was assessed using Box’s M test. All within-subject effects were Greenhouse–Geisser corrected for sphericity of repeated measures. The Greenhouse–Geisser epsilon ( for attenuation of degrees of freedom is reported for all repeated measures. Because was equal to or greater than .80 for all analyses, a violation of the sphericity assumption was unlikely (Stevens, 1996). Estimates of effect size are reported for all ANOVAs and MANOVAs (partial eta squared; η²).

**Results**

Did Mood Change Differ between Conditions?

A MANOVA of POMS change scores (poststress minus baseline) revealed significant differences between the stressor conditions, $F(12,254) = 4.8, p < .001, η² = .19$. As seen in Figure 1, group differences on all POMS scales were observed (relaxed–anxious: $F(2,132) = 3.5, p < .05, η² = .05$; elated–depressed: $F(2,132) = 17.6, p < .001, η² = .21$; energetic-tired: $F(2,132) = 12.1, p < .001, η² = .15$; agreeable–hostile: $F(2,132) = 14.9, p < .001, η² = .18$; confident–unsure: $F(2,132) = 20.3, p < .001, η² = .24$; clearheaded–confused: $F(2,132) = 13.1, p < .001, η² = .17$). Overall, subjects exhibited a lowering of mood in response to the negative stressor, and either no change or a heightening of mood in response to the positive stressor. Mood response of participants in the neutral condition fell between the positive and negative stressor groups, and tended to be mildly negative. Increased anxiety was reported in all three conditions, but it was greatest following negative stress and least following the positive stressor (see Figure 1).

Did Cortisol Output Differ between Conditions?

Data for 2 subjects were not interpretable, probably because of contamination of the samples, and were dropped from the analyses. Cortisol data was based on 133 participants: 47 in the negative stress condition, 44 in the positive stress condition, and 42 in the neutral condition. A two-way (Condition × Experimental Phase) ANOVA on mean cortisol output revealed no significant main effect of stressor condition, nor were any significant interactions found (see Figure 2). There was a main effect of experimental phase, $F(3,390; ε = .81) = 5.8, p < .005, η² = .04$, which was largely due to differences between mean levels of cortisol during the attention task and recovery phases (Bonferroni correction: $α = .02: F(1,130) = 23.1, p < .001, η² = .15$). No differences between relaxation levels of cortisol and those obtained during the stressor
and attention task phases were observed. In contrast to the results obtained for mood, the experimental manipulations did not differentially influence cortisol levels, nor did they elicit a significant stress-induced rise in cortisol.

**Did Attention and Recognition Memory Differ between Conditions?**

To simplify the reporting of hemifield effects, results of the spatial cueing task are described by the direction of the attentional shift in reference to the pretarget cue. On valid trials, right and left hemifield trials refer to shifts of attention toward words appearing in the right and left hemifield, respectively. On invalid trials, right and left hemifield trials refer to shifts of attention away from words appearing in the opposite hemifield (the left and right hemifield, respectively). These data are presented in Table 1. To assess the validity of the spatial cueing paradigm, a four-way ANOVA (Condition × Word Type × Hemifield × Cue Validity) was conducted on reaction time data. Reaction time to validly cued targets was significantly faster than invalidly cued targets (main effect of cue validity: $F(1,132) = 140, p < .001$, $\eta^2 = .51$). This finding attests to the validity of the modified spatial cueing paradigm. Subsequent analyses were conducted on valid and invalid trials separately.

No significant findings regarding word type or stressor condition were observed on valid trials. A three-way ANOVA on invalid trials revealed a significant main effect of hemifield, $F(1,132) = 31.8, p < .001$, $\eta^2 = .19$, and a trend for significance for the Condition × Word Type × Hemifield interaction, $F(4,264; \epsilon = .92) = 2.23, p < .075$, $\eta^2 = .03$. For the latter interaction, planned comparisons (Bonferroni correction: $\alpha = .01$) were performed to compare negative words with positive and neutral words within each of the stressor conditions. Shifts of attention away from left hemifield words were significantly faster for negative words than neutral or positive words in the negative stressor condition, $F(1,46) = 7.8, p < .01$, $\eta^2 = .15$. This effect was not observed following the positive stressor or the neutral condition, nor was it found for shifts of attention away from right hemifield words. Thus, subjects shifted...
away more rapidly from a negative cue than a positive or neutral cue following the aversive stressor challenge.

A two-way ANOVA (Condition × Word Type) on memory data showed a significant main effect of word type, $F(2, 264; \epsilon = .95) = 78.2, p < .001$, $\eta^2 = .37$, indicating that recognition (mean ± SD: Bonferroni correction: $\alpha = .02$) of negative words, 10.9 ± 4.2, was superior to neutral, 6.9 ± 3.9; $F(1, 132) = 115.6, p < .001$, $\eta^2 = .47$, and positive words, 10.2 ± 4.3; $F(1, 132) = 6.2, p < .05$, $\eta^2 = .05$. In addition, recognition of positive words was superior to neutral words, $F(1, 132) = 89.6, p < .001$, $\eta^2 = .40$. No main effect of condition or Condition × Word Type interaction was found. This result suggests that negative and positive words are encoded in memory more readily than neutral words.

**Were the Effects of Stress on Attention Influenced by Self-Reported Depressive and Anxious Symptoms?**

Subjects were classified as low dysphoric or high dysphoric based on a median split of Beck Depression Inventory scores. As expected, the Beck Depression Inventory correlated with baseline POMS depression, $r = -.33, p < .001$, and anxiety, $r = -.37, p < .001$, scores, but not with stress-induced POMS mood change (depression: $r = .03$, n.s.; anxiety: $r = .01$, n.s.). The mean Beck Depression Inventory score in high ($n = 58$) and low dysphoric ($n = 77$) subjects was 10.1 ± 4.6 (range 5–29) and 1.7 ± 1.5 (range 0–4), respectively. The groups were unequal because of the high prevalence of scores at the median (17 subjects with a Beck Depression Inventory score of 4). We opted to classify these subjects as low dysphoric subjects. The breakdown between stressor conditions for low and high dysphoric subjects was 23 and 22 in the positive stressor, 25 and 22 in the negative stressor, and 29 and 14 in the neutral conditions, respectively. A MANOVA of POMS scores revealed significant differences in mood state between high and low dysphoric participants at baseline, $F(6, 124) = 5.0, p < .001$, $\eta^2 = .19$, but not for mood change scores (data not shown).

Four-way ANOVAs (Group × Stressor Condition × Word Type × Hemifield) revealed no significant findings for valid trials, but a significant Group × Condition interaction for invalid trials, $F(2, 129) = 3.13, p < .05$, $\eta^2 = .05$. This interaction was due to a significant group difference (Bonferroni correction: $\alpha = .02$) in the negative stressor condition, $F(1, 45) = 6, p < .02$, $\eta^2 = .12$, and is depicted in Figure 3. Low dysphoric subjects were more efficient in shifting attention away from all stimuli following the negative stressor condition than either the positive or neutral conditions. High dysphoric subjects, however, were slower to disengage from all stimuli following the negative stressor than the positive stressor or the neutral condition. The same analyses were conducted in subjects with high and low ratings on the State-Trait Anxiety Inventory, but did not yield significant findings (data not shown).

**Predicting Cortisol Change during the Experiment, Attentional Disengagement, and Poststress Cortisol Levels**

Hierarchical multiple regressions were conducted on (1) the magnitude of cortisol change from baseline, (2) disengagement from emotional words, and (3) cortisol levels during recovery. The order of entry of variables into the regression was based on the temporal sequence of events during the experiment, from baseline state variables to reactive measures. The first regression examined the relative contributions of symptoms of depression, anxiety, and stress-induced mood change in predicting the magnitude of cortisol change from baseline. The measure of cortisol change was the difference between the lowest cortisol value during the relaxation phase and the highest value achieved during the stressor or attention phases of the experiment. The predictors and order of entry for each step were as follows: (1) symptoms of depression and anxiety (score on the Beck Depression Inventory and the State-Trait Anxiety Inventory), (2) baseline cortisol (mean production during relaxation phase), and (3) mood change (sum of all POMS change scores). The regression equation was significant, $R = .55, F(4, 128) = 13.5, p < .001$, with the four predictors accounting for 27% (adjusted $R^2$) of the variance. Most of the variance (adjusted $R^2 = .24$) was accounted for by cortisol levels at baseline, $\beta = 0.51; t = 6.8, p < .001$. However, both the baseline ratings of depression, $\beta = -23; t = -2.8, p < .01$, and anxiety, $\beta = 0.18; t = 2.2, p < .05$, but not mood change, were significant predictors of the magnitude of the cortisol change from baseline. Thus, high scores on the Beck Depression Inventory and the State-Trait Anxiety Inventory were predictive of lower and higher peak cortisol, respectively, during the experimental manipulations.

The second hierarchical regression was conducted to assess whether the mood response to stress and cortisol levels were predictive of the efficiency in which subjects disengaged attention from negative words, using the mean difference in reaction time between negative and neutral words on invalid trials. The predictors and order of entry for each step were the same as those of the previous regression, except that the magnitude of cortisol change from baseline was entered in Step 4. For shifts away from left hemifield negative words, the regression equation was significant, $R = .30, F(5, 127) = 2.4, p < .05$, with the five predictors accounting for 5% (adjusted $R^2$) of the variance. Only mood change on the POMS predicted disengagement from negative words, $\beta = 0.25; t = 2.9, p < .005$, accounting for all 5% of the variance in the equation. The regression was repeated for shifts of attention away from right hemifield words and for positive words. In both
instances, the results failed to reach significance (data not shown). These results indicate that negative mood change in response to the experimental manipulations was associated with the tendency to shift away from negative words in the left hemisphere. The hypothesis that cortisol levels are associated with selective attention to emotional words however, was not supported.

The third hierarchical regression was performed to assess whether selective attention to positive and negative words was predictive of cortisol levels during recovery, as indexed by the lowest cortisol value achieved during the recovery phase of the experiment. Predictor variables were entered in the following steps: (1) symptoms of depression and anxiety, (2) mood change, (3) peak cortisol level achieved during the stressor phase of the experiment, and (4) mean difference in reaction time between negative and neutral words, and positive and neutral words on invalid trials. The regression equation was significant, $R = .68, F(6,126) = 18.3, p < .001$, with the six predictors accounting for 44% (adjusted $R^2$) of the variance. As expected, peak cortisol response during the stressor phase was predictive of levels of cortisol during the recovery phase, $\beta = 0.62; t = 9.2, p < .001$, accounting for most of the variance (adjusted $R^2 = 0.40$). Ratings of anxiety and mood change did not predict cortisol recovery, but scores on the Beck Depression Inventory did, $\beta = 0.17; t = 2.4, p < .05$. Disengagement from negative words, $\beta = 0.19; t = 2.4, p < .05$, but not positive words, was associated with lower cortisol during recovery, even after accounting for peak cortisol and ratings of depression. This analysis was repeated for shifts of attention away from words in the right hemisphere; selective attention was not predictive of cortisol recovery (data not shown). In sum, high scores on the Beck Depression Inventory were associated with elevated cortisol levels during recovery, whereas shifts of attention away from negative words were associated with lower cortisol levels.

**Discussion**

The aim of the study was to examine the mood, adrenocortical, and attentional response to a social stressor characterized by loss or success. The stressor conditions altered mood in the expected direction, supporting the validity of the stress induction. Salivary cortisol levels, however, did not increase following the stressor manipulation, nor did they differentiate between the conditions. Overall, the findings can be summarized along two lines. First, the initial prediction that individuals would selectively attend to negative stimuli in response to aversive stress was not supported. In contrast, the aversive stressor elicited a rapid disengagement of attention from negatively valenced words, but not from positive or neutral words. Shifts of attention away from negative information were associated with a more pronounced negative mood response to the experimental conditions, and lower cortisol levels during the recovery phase of the experiment. These data suggest that rapid attentional disengagement from negative words occurred in response to stress-induced negative affect, perhaps as an adaptive means to regulate emotional arousal. Second, participants scoring above the median on the Beck Depression Inventory (the dysphoric group) were slow to disengage attention from all stimuli following the aversive stress condition, but not following either the positive stressor or neutral condition. This response may represent a stress-induced decrease in cognitive flexibility and/or processing efficiency. Further, high scores on the Beck Depression Inventory were predictive of lower peak cortisol during the stress phase of the experiment, and higher cortisol levels during the recovery phase. Taken together, these results suggest that under conditions of stress, dysphoric individuals are hampered by cognitive processing mechanisms that are maladaptive and by HPA function that is atypical.

**Disengaging Attention and Coping with Stress**

Although the rapid disengagement of attention from negative words was inconsistent with certain theories of attention and emotion (Derryberry & Tucker, 1994; Lang, Bradley, & Cuthbert, 1998), similar findings have been observed in the normal control groups of studies investigating attentional biases in clinical or high anxious populations (Bradley et al., 1997; Bradley, Mogg, White, & Millar, 1995; MacLeod, Mathews, & Tata, 1986; Mogg, Bradley, Williams, & Mathews, 1993), and in individuals with low levels of trait anxiety and depression (Byrne & Eysenck, 1995; Gotlib, McClatchlan, & Katz, 1988; McCabe & Gotlib, 1995; Stewart, Conrod, Gignac, & Pihl, 1998). Healthy individuals who worry about future cardiac problems were reported to avoid, rather than attend to, cardiac-related words on an attentional search task (Constans, Mathews, Brantley, & James, 1999). Also, subjects with low trait anxiety tended to avoid negative information during the naturalistic stress of examinations (MacLeod & Mathews, 1988; Mogg, Bradley, & Hallowell, 1994). Although attentional avoidance has been observed in some studies, particularly among healthy individuals who report low ratings of depression and anxiety, it is not a particularly robust phenomenon.

The use of a spatial cueing task may be one reason why attentional avoidance was observed in the current study. Unlike other measures of attention (Lang et al., 1998; Mogg & Bradley, 1998), spatial cueing allows for avoidant reactions to emotional stimuli through its disengagement trials. Also, the stimuli used in this task were presented at an exposure duration allowing full conscious awareness, and stimuli of the same affective valence were grouped together in blocks. As a result, participants could invoke intentional strategies more readily to meet the demands of the task. Stormark, Field, Hugdahl, and Horowitz (1997) found that alcoholics were slower to shift away (selective attention) from alcohol-related words than neutral words when the words were presented briefly (100 ms), and faster to shift away (avoidance) when words were presented for a longer exposure duration (500 ms). This latter finding was remarkably similar to the attentional avoidance observed in the present study. Perhaps, participants in the present study attempted to terminate an emotional response to repetitive loss by avoiding negative stimuli. Thus, prolonged exposure to an emotional cue may initiate intentional responses to self-regulate by way of attentional avoidance, whereas brief exposure times may trigger reflexive or automatic processes that capture attention (Öhman, Flykt, & Lundqvist, 2000). Alternatively, the rapid shifts of attention away from negative words could conceivably reflect faster processing of negative stimuli, allowing participants to efficiently interrupt processing, disengage attention, and detect the contralateral cue during invalid trials. Although this explanation is plausible, the avoidance interpretation is consistent with the results of other studies using tasks other than spatial cueing (Constans et al., 1999; Stewart et al., 1998).

Recent theoretical accounts of self-regulation highlight the importance of attention in modulating behavioral propensities (i.e., temperament, personality) and affect (Derryberry & Rothbart, 1997; Posner & Rothbart, 2000). According to these authors, the ability to disengage attention efficiently represents a critical dimension of self-regulatory behavior, one which can counteract other temperamental dispositions or the tendency to experience negative affect. Our finding that high ratings of stress-induced negative affect were associated with rapid shifts of attention away from negative words...
on a subsequent task is consistent with this idea. The relationship between attentional avoidance and lower levels of cortisol during the recovery phase of the experimental protocol suggests a possible role of attention in regulating adrenocortical function. However, because stress-induced HPA activation was not observed in this study, the role of attention in the regulation of the adrenocortical stress response could not be determined.

**Stress Response in Dysphoric Participants**

There was evidence of an atypical stress response in participants with elevated Beck Depression Inventory scores. First, reaction time to disengage attention, irrespective of word valence, was slower in dysphoric than nondysphoric participants following the aversive stressor, but not following the other conditions. Consistent with this finding, slow attentional disengagement from a nonverbal cue was associated with higher ratings of negative affect in response to the presentation of a distressing film (Compton, 2000). Second, elevated scores on the Beck Depression Inventory were associated with low peak cortisol during the experimental manipulations and with high cortisol levels during the recovery phase of the study. These findings are reminiscent of the elevated basal cortisol and greater diurnal variation in cortisol secretory patterns observed in clinically depressed individuals (Stokes & Sikes, 1987). In addition, a blunted cortisol response to stress has been observed in depressed patients (Croes, Merz, & Netter, 1993; Trestman et al., 1991). A question raised by these data, therefore, is whether impaired attentional disengagement and abnormalities in HPA functioning are vulnerability markers of depression. Cognitive biases (Gilboa & Gotlib, 1997; Nolen-Hoeksema, 1987), general emotional instability (Ellenbogen & Hodgins, 2001; Lauer et al., 1997), and a heightened sensitivity to stressor and neurobiological challenges (Benkelfat, Ellenbogen, Dean, Palmour, & Young, 1994; Holsboer, Lauer, Schreiber, & Krieg, 1995; Zahn, Nurnberger, & Berrettini, 1989) have all been proposed as vulnerability factors of depression. Perhaps, slow attentional disengagement precipitates maladaptive coping strategies such as excessive perseveration or rumination on negative themes. Interpretation of these findings as possible vulnerability factors for depression, however, awaits replication in studies of participants chosen a priori for risk for depression.

**Attentional Avoidance and Asymmetry**

Unexpectedly, the attentional avoidance response was observed only when shifting attention away from negative words in the left hemisphere (right hemisphere) following the negative stressor. Electroencephalographic studies of brain activation have reported an association between negative affect and greater right than left hemispheric activation in nonclinical populations (Davidson, 1998). Of interest, greater right than left parietal activation, critical for attentional orienting (Posner & Petersen, 1990), was observed in individuals who exhibited somatic anxiety in response to distressing narratives (Heller, Nitschke, Etienne, & Miller, 1997). Because the attentional avoidance was associated with negative mood change, it is possible that the negative stressor stimulated asymmetrical brain activation favoring the right hemisphere. Under conditions of right hemisphere activation, a facilitation of contralateral shifting (away from the left hemisphere) would be expected (Heilman, 1995).

Interestingly, the association between cortisol levels during the recovery phase of the experiment and attentional avoidance of left hemisphere words is consistent with a reported asymmetry in the regulation of adrenocortical function favoring the right hemisphere (Kalin, Larson, Shelton, & Davidson, 1998; Wittling, 1995). Although speculative, interpretations along these lines may help explain the asymmetry of attentional avoidance observed in the present study.

**Limitations and Conclusions**

A number of limitations warrant consideration. First, cortisol secretion did not differentiate between the stressor and neutral conditions. Because computer feedback of Stroop performance followed each block of trials during the neutral condition, it is possible that participants were “competing” against themselves. The neutral condition may have stimulated higher task involvement than the other conditions: The repeated winning and losing during the stressor conditions may have decreased task involvement over the course of the stressor trials. In addition, the neutral condition was perceived as ambiguous by some participants. All of these factors may have accounted in part for the finding that cortisol production did not vary with conditions. Second, the expected cortisol increase between the relaxation and stressor phase of the experiment was not observed. Possible reasons include high baseline values during the relaxation phase, sporadic rather than sustained cortisol production during the stressor and attention phases, and individual variations in the timing of the cortisol response. Finally, the presentation of words for a single exposure duration limits the generalizability of the present findings. Presentation of words briefly, or outside of conscious awareness, would perhaps have generated different results. Future studies of spatial cueing with emotional stimuli need to test the effects of different exposure durations.

In conclusion, the results suggest a mechanism whereby individuals cope with aversive stress by shifting attention away from negative information. Attentional disengagement may represent a means of regulating negative emotion, and may also influence cortisol levels as well. In addition, the present study draws attention to possible mechanisms of dysfunction in psychopathology, in demonstrating that dysphoric individuals exhibit subtle changes in the stress-sensitive attentional and adrenocortical systems, perhaps indicating a vulnerability to clinical depression. Studies of clinical and high risk populations will be required to examine further this line of assumptions; whether, for example, attentional disengagement difficulties are a feature of stress-related forms of psychopathology.

**REFERENCES**


Stress and emotional information processing


Table A1 shows the words used in the spatial cueing task.

<table>
<thead>
<tr>
<th>Positive</th>
<th>Negative</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Glory</td>
<td>17. Loser</td>
<td>33. Chair</td>
</tr>
<tr>
<td>2. Success</td>
<td>18. Gloomy</td>
<td>34. Yearly</td>
</tr>
<tr>
<td>10. Talented</td>
<td>26. Inferior</td>
<td>42. Interval</td>
</tr>
<tr>
<td>11. Champion</td>
<td>27. Helpless</td>
<td>43. Segment</td>
</tr>
<tr>
<td>13. Superior</td>
<td>29. Defeated</td>
<td>45. Duration</td>
</tr>
<tr>
<td>15. Conquest</td>
<td>31. Hopeless</td>
<td>47. Corridor</td>
</tr>
<tr>
<td>16. Flourish</td>
<td>32. Disgrace</td>
<td>48. Assembly</td>
</tr>
</tbody>
</table>

APPENDIX

Table A1. Words Used in Spatial Cueing Task

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